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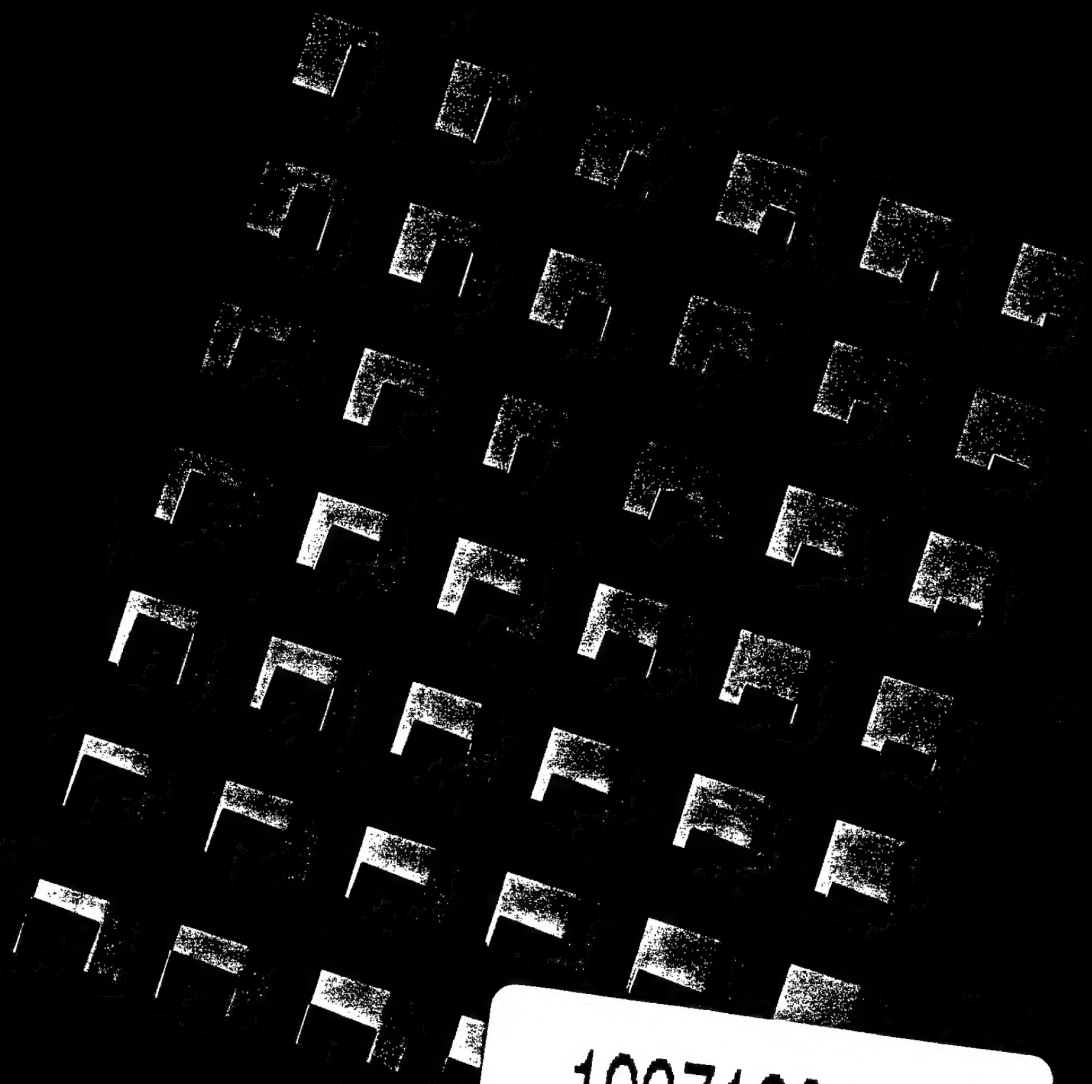

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Management uittreksel TNO Technische Menskunde, Soesterberg

titel:	Effecten van vermoeidheid en sociale omgeving op prestatie: individuele en team taken
auteurs:	Mr.drs. C.Y.D. van Orden, prof.dr. A.W.K. Gaillard en J.J. Langefeld
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14. SUPPLEMENTARY NOTES

15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTES))

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The tasks differed in their sensitivity to fatigue. Performance on the two simplest tasks (RTT and MST) deteriorated most over night, compared with the more complex CMT and the team task. One should realise, however, that during the experiment a rather strong learning effect occurred on both the CMT and the team task. This learning effect might have interfered with the fatigue effects. Nevertheless, it can be concluded that cognitive complex, and therefore maybe also more interesting tasks, are less vulnerable to fatigue than simple tasks.
In general, subjects performed better on the individual tasks when they worked in presence of another subjects, as compared to alone. This was especially the case in the last sessions. So, the more tired one is, the more one profits from working with someone else. Subjects who got feedback on their individual scores performed better than those who got group feedback. It seems that 'social loafing' indeed can be prevented by making all individual group members' scores public. A comparison with the previous experiment shows that the performance of subjects who get individual feedback is even better if they are promised a bonus.
Providing individual feedback is thought not to be very effective when people work on interdependent team tasks, since in such tasks they can hardly influence their own individual performance. This hypothesis that individual feedback is only efficient with individual tasks and that group feedback is better with interdependent team tasks, unfortunately could not be tested in this experiment, because there was too little variance in the individual scores on the team task.

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Feedback Social Facilitation Social Loafing Sustained Work	Performance Teamwork

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Soesterberg

Effecten van vermoeidheid en sociale omgeving op prestatie: individuele en team taken

C.Y.D. van Orden, A.W.K. Gaillard en J.J. Langefeld

SAMENVATTING

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1 INTRODUCTION

1.1 Introduction

This report describes the fifth in a series of experiments on the combined effects of fatigue and social environment on task performance. This line of research was initiated on request of the Royal Netherlands Army, which was interested in the question how task performance can be kept 'up to the mark' when military personnel has to work clock round.

Due to technological developments, the work environment has changed enormously. Machines and robots continue to take over physical work, and human beings gradually move into a role of 'process controller'. In many situations it is possible that only one person controls a whole system, where in earlier days many people were needed to perform a similar task. Even if from a technological point of view it is possible to let people work alone, from a social-psychological point of view, this may not be a desirable situation. For several reasons people may work better when they are together with one or more colleagues, especially under conditions of stress and fatigue.

The aim of this research is to get insight into the potential fatigue-compensating effects of factors in the social environment. So far, four 24-hour experiments have been carried out in which subjects work (almost) continuously on several tasks. The following factors have been studied:

- sustained work (sleep deprivation and fatigue);
- type of task (cognitive vs. perceptual-motor tasks);
- social facilitation or inhibition (presence of another person during task performance);
- social loafing (manipulated by feedback and bonus structure).

1.2 Theoretical background

1.2.1 Fatigue and task

Effects of fatigue and sleep deprivation have been studied extensively, also in military settings (see reviews by Evans, Mackie & Wylie, 1991; Krueger, 1991). The longer people work, the more tired they get, especially if they are deprived of sleep. The general assumption is that performance deterioration occurs because the level of activation decreases.

Not all tasks are negatively affected by fatigue and sleep deprivation to the same extent. Physical tasks, such as marching or carrying loads, can be carried out rather efficiently for relatively long periods of time (e.g., 6 hours continuously). Mental tasks seem to be more sensitive to fatigue (Krueger, 1991; Belenky et al., 1993; Angus & Heslegrave, 1983). Holding (1983) concludes that performance decrements especially occur on simple repetitive tasks. With more complex, and therefore maybe more stimulating tasks, the effects are less

pronounced. The distinction between complex and simple tasks is based on the amount of information processing activities required. Simple perceptual-motor tasks usually require less mental activity (e.g., recognising figures, pressing a button), whilst more complex tasks, such as calculating or decision making, require more mental activity (e.g., May & Kline, 1987).

The fact that complex cognitive tasks are less vulnerable to fatigue, is not necessarily explained by complexity of the task only. Maybe, more complex tasks also are more stimulating and therefore more intrinsically motivating than simple (perceptual-motor) tasks, which usually are quite boring. Allnutt, Haslam, Rejman and Green (1990) for example found that performance on several cognitive tasks in a full flight simulator did not deteriorate due to sleep deprivation, whereas boring laboratory tasks of similar cognitive complexity were affected. 'Complexity' and 'boredom' seem to be two different task dimensions. Simple tasks can be very stimulating (e.g., certain video games), and complex tasks can be really boring (e.g., calculation jobs).

Another explanation for the larger sensitivity of perceptual-motor tasks could be the difference in task duration. Effects of fatigue and sleep deprivation on task performance are mostly studied in two different 'research traditions':

1 *sustained work research*: mostly perceptual-motor tasks; long task duration;
2 *sleep deprivation research*: both cognitive and perceptual-motor tasks; subjects are kept awake a whole night, and in the morning they have to perform a task.

This means that in most studies cognitive tasks are administered for shorter periods of time than simple tasks, which could lead to spurious results (Evans et al., 1991). Under sleep loss people can compensate for lowered activation, but only for a short period of time (Raaijmakers, 1990; Angus, Heslegrave, Pigeau & Jamieson, 1987). If the task has to be performed for a longer period of time, then it is harder to keep mobilizing energy, and to remain alert. For short periods of time, fatigue effects can be compensated by mental effort from the task performer. Such compensation is even more effective when feedback on performance is provided (Gaillard & Steyvers, 1989). If the task duration is too long, however, even mental effort and feedback do not help anymore. For this reason, the current line of research uses continuous work of long duration, both for simple and complex tasks.

To summarize: in general, complex cognitive tasks are less affected by fatigue and sleep deprivation than simple perceptual-motor tasks. However, if the duration of the task is very long, even complex cognitive tasks suffer from fatigue. Besides complexity and task duration, the intrinsic motivation may play a role.

1.2.2 Social facilitation: another person's presence

From the social psychological literature, it is known that several easy tasks, such as winding fishing reels (Triplett, 1898, in Guerin, 1993, p. 9), or a memory search task (Pruijn, 1986), are performed better by subjects in another person's presence, than alone. This phenomenon is called social facilitation (Cotrell, 1972; Manstead & Semin, 1980; Sanders, 1981; Pruijn &

Vlek, 1986). The reverse is also found: difficult tasks such a 'mastermind'-like task (Pruijn, 1986), or a complex maze (Jackson & Williams, 1985) are performed better when alone. The presence of another person in these situations interferes with good performance ('social inhibition'). Experiments in which both simple and complex tasks are used confirm this 'rule of thumb' that simple tasks are facilitated, and complex tasks inhibited by other people's presence (Guerin, 1993, p. 146).

There are two possible explanations for this phenomenon: arousal and information processing capacity.

1 People get aroused by another person's presence. When people are aroused, 'dominant responses' will pop up first when they perform a task. Dominant responses are those responses that are given automatically, by routine. With simple tasks, dominant responses do not hinder good performance, since one is not required to think hard and it is efficient to rely on automatisms. With complex tasks, however, another person's presence results in performance decrements because dominant responses usually are not the appropriate ones (Zajonc, 1965). Furthermore, to perform well, activation of the task performer needs to be at a certain level, not too low and not too high (inverted U-curve). A complex tasks is already arousing in itself, and extra arousal by another person's presence is counterproductive. A simple task is not very arousing in itself, so extra arousal from another person's presence might have a stimulating effect, which positively affects the performance.
2 The presence of another person during task performance requires attention of the performer. Unconsciously, some attention is paid to this other person: maybe the task performer wonders why this other person is there, or how this person would evaluate his performance. The presence of another person poses extra demand on the information processing capacity, which means that less is available for the task. With simple tasks, this is no problem, since not much information processing capacity is needed to perform the task. With complex tasks, however, all capacity is needed for the task itself (Sanders, Baron & Moore, 1978).

In a normal situation, complex tasks are performed better when the task performer is alone, simple tasks are done better when another person is present. In cases of sleep deprivation, the arousal level falls. Arousal decrements are strongest with simple tasks, because they are hardly stimulating themselves. Complex tasks suffer less from sleep deprivation or fatigue, because they are intrinsically motivating. Therefore, another person's presence is expected to be more effective in compensating fatigue effects with simple tasks, than with complex tasks.

1.2.3 Social loafing

If people work on a task together, there is a risk that group members put less effort in the task, compared with the situation that they would work alone. This phenomenon is called 'social loafing'. It is shown to occur with physical tasks, such as pulling a rope (Ringelmann, 1913; Ingham, Levinger, Graves & Peckham, 1974), shouting and clapping (Latané, Williams & Harkins, 1979), and pumping air (Kerr & Bruun, 1981), as well as with cognitive tasks,

such as vigilance (Harkins & Petty, 1982), solving mazes (Jackson & Williams, 1985), and evaluating essays (Petty, Harkins, Williams & Latané, 1977).

The occurrence of social loafing seems to depend on the following factors:

1 Individual contributions to the group result cannot be identified (Williams, Harkins & Latané, 1981; Harkins, 1987);
2 There is a great chance of redundant effort by the individual team members (Harkins & Petty, 1982);
3 Cohesion in the group is low (Williams, 1981);
4 Team members feel very little individual responsibility for the group output (Petty et al., 1977).

In the studies mentioned above, relatively simple tasks were used. The general conclusion from these studies is that working collectively on a task results in performance decrements, because people are inclined to put less effort in the task. This conclusion is not true for all types of tasks, however. With complex tasks, social loafing does not occur *per sé* (Harkins, 1987). This can be explained by combining social facilitation and social loafing theory (cf. § 1.2.2): complex tasks usually are stimulating and therefore arousing; if people get extra aroused by the idea that other people present can evaluate their performance, they get too aroused to perform their task well. Working collectively (in a group, where the individual contribution to the group result cannot be identified) means that one source of arousal disappears, namely the possible evaluation of one's performance by others. So with complex tasks, working collectively could result in performance increases instead of decrements.

To summarise: under normal conditions, working collectively on simple tasks results in social loafing; with complex tasks, however, it might even have a beneficial effect. Under tiring conditions such as our 24-hour experiments, these effects are expected to be even stronger than under normal conditions. Social loafing is expected to occur when subjects work on simple tasks, and these social loafing effects get stronger over time. In contrast, complex tasks are less affected by sleep loss and there is a lower chance of social loafing to occur.

1.2.4 Feedback

Social loafing can be studied by giving a group of subjects *public* feedback either on all group members' individual scores (individual feedback), or on the group score only (group feedback). Social loafing is expected to occur in the group feedback condition: if subjects only get feedback on the group results, their performance will be worse than when they get feedback on their individual results. This is due to the identifiability of the individual contributions to the group result. Based on several experiments, Williams et al. (1981) concluded that social loafing can be prevented by making each subject's performance identifiable. For that reason, individual feedback is expected to be far more stimulating than group feedback (Conlon & Barr, 1989). This effect is expected to hold over time. If performance *decrements* over time are made identifiable as well, this might prevent strong perform-

ance deteriorations. So under tiring conditions, subjects with individual feedback are expected to keep performing better than subjects with group feedback.

1.3 Overview experiments 1-4

The focus of the first two experiments was on the question which tasks, differing in cognitive complexity, are affected most by fatigue and sleep deprivation. It was also investigated whether negative effects of fatigue on task performance could partly be compensated by working in presence of another person (social facilitation). The results of the first two 24-hour experiments (Kerstholt, Van Orden & Gaillard, 1994; Van Orden & Gaillard, 1995) showed that fatigue had a greater impact on simple perceptual-motor tasks compared with complex cognitive tasks. Social facilitation effects were hardly found. Only with the simple perceptual-motor task, subjects working in pairs (in presence of another person) outperformed the ones working alone, although the effects were not very strong.

Informal observations of the subjects during the experiment suggested that the atmosphere in the group overruled the presence of another subject during task performance. 'Cohesive' groups seemed to be better able to cope with the situation. To study this hypothesis, an attempt was made to manipulate cohesiveness in a third experiment (Van Orden & Gaillard, 1996). Half of the subjects were treated as group: [1] at arrival they were divided into two groups of four persons; they had to wear blue or red badges and were called the blue and the red group; [2] they could win a group bonus; [3] all group activities were carried out in the same group. The other half of the subjects were treated as individuals (same colour badges, individual bonus and group activities in changing groups). Subjects in the (cohesive) group condition were expected to outperform the ones in the individual condition (cf. e.g., Evans & Dion, 1991).

Contrary to what was expected, subjects in the individual condition performed much better than those in the group condition. Since no significant differences in cohesion were measured between the two treatments, the cohesion manipulation had not been successful. The performance differences seemed to be due to the bonus structure used: subjects in the individual condition were highly motivated to strive for their individual bonus, whilst in the group condition 'social loafing' could have occurred.

To test whether social loafing could explain these results, a fourth experiment was carried out (Van Orden, Gaillard & Langefeld, 1996), with the same design as the previous experiment. One major adjustment was made: subjects got public feedback on their results, either on all group members' individual results, or on the group results only. Social loafing was expected to occur in the group feedback condition, but not in the individual feedback condition. Subjects with individual feedback indeed performed much better than those with group feedback. This suggests that the results of the third experiment could indeed be explained by social loafing.

Since the same design was used in both studies, the results of the fourth and the third experiment could be compared. In the third experiment subjects were treated either as individuals or as groups, which means that they were promised either an individual or a group bonus for good performance. In this third experiment they did not get feedback. In the fourth experiment all subjects were treated as groups, which means that they were promised a group bonus for good performance. They got either individual or group feedback. The comparison between those two experiments made it clear that the negative effects of fatigue on task performance can (partly) be compensated by adding at least one individual aspect to the task environment: subjects in the individual bonus/no feedback condition or in the individual feedback/group bonus condition performed better than those in the group feedback/group bonus condition or in the group bonus/no feedback condition.

Since in the fourth experiment feedback was given in combination with group bonuses, no conclusions could be drawn on the effects of feedback alone, without bonus. In order to study these effects without potentially interfering effects of bonuses, the current study was designed. Subjects got either individual or group feedback on their results, without a bonus. So far, the group bonus had always been used as a cohesion enhancing manipulation. Now that is was removed from the experimental design, another cohesion manipulation had to be put in place. An interdependent team task was added, which had to be carried out five times. Furthermore, all four person teams had some practice sessions two days before the experiment. Subjects could be expected to know each other relatively well and to form a rather cohesive group.

Besides studying the effects of feedback alone, the feedback structure could be assessed in relation to task structure. In the previous studies, only individual tasks were used. Group scores were based on the sum of the individual group members' scores. In such a case, one speaks of a *nominal group*. The first four experiments showed that in nominal groups individual feedback better compensated the effects of fatigue than group feedback, because giving group feedback allows social loafing to occur. In *interdependent teams,* however, a different situation exists. One speaks of interdependent teams, if the team members have to communicate and coordinate their actions in order to perform the team task. Team members have their own sub-task and their own unique expertise or knowledge, that they have to share with other team members. The final team performance depends on the quality of all the separate sub-tasks. Team members rely heavily on each other to achieve a good result. With interdependent team tasks, as opposed to nominal groups who work on individual tasks, feedback on a team level might be more effective, since the individual team members can hardly influence their own individual scores (Saavedra, Earley & Van Dyne, 1993). In such a situation, individual feedback would only be experienced as frustrating.

1.4 Design and summary of hypotheses

Task and fatigue

Subjects worked on several tasks for 24 hours continuously (sleep deprived). Three and a half hours work periods were alternated with half an hour rest periods. Three individual tasks were used: the Reaction Time Task (RTT) (Frowein, Gaillard & Varey, 1981); the Memory Search Task (MST) (Boer, Gaillard & Jorna, 1987); and the Contaminant Monitoring Task (CMT: Hockey, Sauer & Abbott, 1993). These tasks differ in complexity and the amount of information that needs to be processed. The RTT and MST are relatively simple tasks, the CMT is more complex. With the RTT, after some trials the information processing goes almost automatically. With the MST one has to stay alert, since the letters to be remembered change with every trial. The CMT is the most complex task of the three, since it requires memory and calculating skills. The RTT is the least intrinsically stimulating (i.e., the most boring) task of the three. It was expected that the RTT and the MST would be affected rather strongly by fatigue and sleep deprivation, and the CMT less. In addition to the individual tasks an interdependent team task was used. This task was expected to be less vulnerable to sleep deprivation and fatigue, because of its stimulating character.

Social facilitation

The three individual tasks were carried out twice: alone or in presence of another person. It was assumed that fatigue effects partly could be compensated by working in pairs, so that the performance on all tasks would be best when subjects worked with another person in the same room. This effect was expected to be strongest at the end of the experiment, when subjects got really tired. Furthermore, it was expected to be strongest with the RTT, since that is the most simple task.

Individual versus group feedback (individual tasks)

Subjects were divided into four-person groups. The team tasks were carried out in the same group, and the scores on all individual tasks were summed to obtain group scores. All groups received public feedback on their results. Half of the subjects got feedback on a group level: only the group score was presented. The other half of the subjects got feedback on an individual level. If feedback is provided on a group level only, the individual contribution to the group result cannot be identified, and social loafing is expected to occur. Therefore, subjects who got individual feedback were expected to outperform subjects with group feedback.

Feedback without bonus (individual tasks)

In this experiment, subjects got no bonus, like in the previous study. This was done in order to gain insight into the effects of feedback alone. In the previous study it was already shown

that subjects in the individual feedback condition performed better than subjects in the group feedback condition. However, from that study it was not clear whether these effects were really due to the feedback structure itself, or that the effects of bonus had interfered. To study this, bonus was left out of the current experiment. Bonus and feedback are expected to have somehow similar motivating effects, and therefore subjects [1] with individual feedback and a bonus are expected to be the best performers, followed by [2] individual feedback without a bonus, [3] group feedback with a bonus, and finally [4] group feedback without a bonus.

Task and feedback (individual and team tasks)

From the previous study, it was concluded that individual feedback better compensated fatigue effects, than group feedback. Saavedra, Earley and Van Dyne (1993) suggest that for interdependent team tasks group feedback is more efficient than individual feedback. If team members can hardly influence their own scores, because they heavily rely on each other to obtain information or goods in order to do their own individual job, it can be experienced as frustrating to be provided with individual feedback only. In order to test this hypothesis, an interdependent team task was added to the task battery: half of the subjects got feedback on the group score on this task, the other half got feedback on the individual scores. It was expected that group feedback would be more efficient on the team task, and that individual feedback would be more efficient on the individual tasks.

2 METHOD

2.1 Subjects

Thirty two male subjects participated in the study, varying in age from 17 to 28 years, all students from Utrecht University. They were paid a normal TNO fee, including drinks and food.

2.2 Tasks

2.2.1 Individual tasks

Reaction Time Task (RTT)

This task is a visual four-choice reaction task. The reaction stimuli consist of the digits 2, 3, 4 and 5. See Figure 1 for a schematic representation of the task. The digits are degraded, which means that they are hard to recognize: a number of dots are taken from the 'frame' to be positioned at random around the digit. To prevent subjects from learning to respond to the degradation patterns instead of the digits, there are four patterns for each degraded digit. The

digit appears for 1000 ms either on the left or on the right side of the screen. If the subjects see the digit on the right side of the screen, they have to press the buttons on the right side of their response panel, if they see it on the left side, they are supposed to use the left hand buttons. After every trial feedback is provided: correct, incorrect or too late. As opposed to the last experiment, a self-paced version of the task was used. Subjects had 10 seconds to respond.

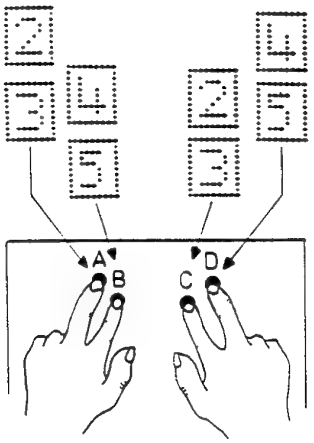

Fig. 1 Schematic representation of the Reaction Time Task.

The total duration of the task was 25 minutes, in which subjects processed approximately 1000 trials. From this tasks, the following measures were analysed:

- number of correct responses;
- number of incorrect responses;
- number of misses (too late).

Since subjects worked at their own pace, the number of correct responses directly depended on their reaction times. For that reason, reaction times were not analysed separately.

Memory Search Task (MST)

As the RTT, the Memory Search Task lasts 25 minutes. In these 25 minutes, subjects process approximately 400 trials, each consisting of the following elements:

- the memory set consisting of four letters, for 1500 ms;
- a fixation cross, for 500 ms;
- a target letter, either belonging to the memory set or not. Subjects have 10s to respond: if the target letter belongs to the memory set, they have to press the 'J'-button, if it does not belong to the memory set, they have to press the 'F'-button.
- as soon as subjects respond to the target, feedback appears on the screen, for 500ms: correct, incorrect, or too late;
- then the next memory set is shown on the screen and the whole cycle is repeated.

The memory set changes with every trial ('varied mapping'). All letters from the alphabet are used, apart from a few letters that resemble each other too much (such as O and Q). In every trial, the memory set is a selection from the total letter set.

Subjects' task was to produce as many correct responses as possible in 25 minutes. The following measures were analysed:

- number of correct responses;
- number of incorrect responses;
- number of misses.

Contaminant Monitoring Task (CMT)

Subjects have to monitor the quality of the work climate in a space ship. The concentration of several gasses in the air should not exceed certain limits. Subjects have to check this by comparing a 'status screen' with a 'reference screen'. Its is possible to switch between these two screens by pressing the space bar. On the status screen, information is shown on the concentration of five different gasses. Four columns of figures are presented: for the *actual situation* in the 'living' and the 'study room', and for the situation in both rooms as it was *thirty minutes before*. On the reference screen, two values are given for five gasses (three of these five differed from the ones shown on the status screen):

SMAC: maximum allowed value for both the living and the study room;

CI: maximum allowed difference between the current value and the value reached thirty minutes before.

Subjects have to check whether values on the status screen exceed the SMAC-values, or whether the difference between the current and the past values exceeds the CI-values. Every status screen contains one failure, no more and no less. Subjects have to find this failure as quickly as possible. If the answer is not correct, the same status screen is presented again, until the correct answer is produced. The duration of the task was twenty minutes. The number of trials processed depended on the work pace. The following measures were analysed:

- number of trials processed;
- number of correct responses.

2.2.2 Team task

An interdependent team decision making task was used in this study: the Tactical Naval Decision Making System (TANDEM) (Weaver, Morgan, Hall & Compton, 1994). TANDEM is a networked radar simulation which requires team members to query and integrate information in order to make accurate decisions regarding the type, threat, and intent of incoming targets. These three tasks are divided over three team members (Alpha, Bravo, Charlie), the fourth team member (Delta) is supposed to engage targets according to the

decisions made by the three others. Subjects receive points based upon the decisions made or consequent actions taken.

The performance measures obtained were as follows:

- individual score: based on the number of points received for a correct decision (100 points), minus the number of points lost for an incorrect decision (100 points). In addition, this score is also impacted by the number of penalty points assessed for allowing incoming targets to get too close;
- number of information items queried;
- total query time: the amount of time spent querying target information.

2.3 Experimentation rooms

In four small experimentation rooms in the basement subjects worked alone on their individual tasks; in two cubicles next to them, they worked in pairs. If subjects worked on individual tasks in presence of another subject in the same room, they were positioned such that they could not look at each others computer screen (all tasks were presented on computer screens), but could see each other.

In the six experimentation rooms in the basement, there is no day light. The room where the subjects could spend the intervals ('subjects room'), also in the basement, does have windows, as well as the 'multi-media laboratory' (MM-lab) on the first floor, where four person teams worked on the networked TANDEM task. In the subjects room there were chairs and tables for all subjects, no reclining seats. Food and drinks were provided there. Coffee and tea were available, alcoholic drinks were not.

The six experimentation rooms in the basement are all provided with video observation cameras and an intercom installation. The experimenter could watch the subjects' behaviours, and was allowed to interfere when subjects seemed to fall asleep. In the MM-lab, the experimenter was in the room with the subjects during task performance, so video observation and intercom was not needed there. Communication between the four subjects during the TANDEM task was only possible via headsets. Moreover, subjects had to press a button on their 'communication panel' before they could get in touch with one of the other subjects. They could only speak with one subject at a time. If the line was engaged, the one who was being called would hear a tone, that warned him that one of the other team members wanted to talk to him. Eye contact was allowed and possible, although subjects were positioned in such a way that they had to turn away from their screen in order to see each other.

2.4 Procedure

The 32 subjects were divided in eight groups of four people each. Three days before the actual experiment, two teams of four people came to the laboratory for about four hours, to practise the TANDEM-task. They were allowed half an hour to study a written instruction. After that, they worked on four practice scenarios of TANDEM, lasting twenty minutes each. All subjects worked on the same position (Alpha, Bravo, Charlie or Delta) all the time, both during the training and the experimental sessions. During the training sessions the experimenter was available to answer questions and solve problems. The two teams rotated, so that one team rested while the other team was working. In between the sessions, team members were allowed to discuss the task and agree on efficient strategies. One twenty minute break was used to have subjects practise the CMT as well. Previous studies had shown strong learning effects from the first to the second experimental session on this task. To avoid this, subjects performed the CMT once before the experiment in a training session.

The actual experiment was carried out in four times 24 hours, within a period of two weeks. Each time, eight subjects (two groups) came to the laboratory. To stress the importance of the group factor, the two groups were provided with badges of a different colour: the blue group and the red group. During the whole experiment, two experimenters were present. Two teams of experimenters rotated: the first shift worked from 6pm until 10pm; the night shift arrived at 10pm and worked until 8:30am the next morning; the first shift came back again at 8:30am and worked until the end of the experiment at 5pm.

Table I Work schedule.

19:00 - 19:30	arrival, instructions
19:30 - 19:45	short practice sessions RTT and MST
20:00 - 24:00	session 1
00:00 - 04:00	session 2
04:00 - 08:00	session 3
08:00 - 12:00	session 4
12:00 - 16:30	session 5

Subjects arrived at 7 pm of the first day. They were asked to hand in their watches, so that they would have no time clues during task performance. After filling out an informed consent, subjects practised the individual tasks RTT and MST shortly. The actual experiment started at 8 pm (see Table I). Subjects worked on the four tasks for 3½ hours, after which they could rest for another ½ hour. This four hour cycle was repeated five times.

Within each session, subjects worked on TANDEM once. The individual tasks were performed twice, either alone or in presence of another subject (in pairs). The duration of TANDEM, the RTT and the MST was 25 minutes, the CMT lasted 20 minutes. Every half

hour subjects changed tasks, and at least every 1½ hour each subject changed rooms (see Table II).

Table II Work schedule session 1 (example from first night; explained in text).

time	4 individual rooms				2 rooms for pairs		large room
20:00-20:30	s 5 MST	s 6 MST	s 7 MST	s 8 MST			ss 1, 2, 3, 4 TANDEM
20:30-21:00	s 5 CMT	s 6 CMT	s 7 CMT	s 8 CMT	ss 1, 2 MST	ss 3, 4 MST	
21:00-21:30	s 5 RTT	s 6 RTT	s 7 RTT	s 8 RTT	ss 1, 2 CMT	ss 3, 4 CMT	
21:30-22:00					ss 1, 2 RTT	ss 3, 4 RTT	ss 5, 6, 7, 8 TANDEM
22:00-22:30	s 1 MST	s 2 MST	s 3 MST	s 4 MST	ss 5, 6 MST	ss 7, 8 MST	
22:30-23:00	s 1 CMT	s 2 CMT	s 3 CMT	s 4 CMT	ss 5, 6 CMT	ss 7, 8 CMT	
23:00-23:30	s 1 RTT	s 2 RTT	s 3 RTT	s 4 RTT	ss 5, 6 RTT	ss 7, 8 RTT	
23:30-24:00	fatigue, mood, and cohesion questionnaires rest						

It is known that performance usually is better right after a break, as compared to half-way sessions (Pigeau & Naitoh, 1995). Therefore, an attempt was made to balance the order of the tasks over nights. For TANDEM the order differed within nights: half of the 32 subjects started each session doing TANDEM, half of the subjects performed this task after 1½ hours of work. As far as the individual tasks is concerned, the order was changed between nights: in nights 1 and 3 the order was MST, CMT, RTT; in nights 2 and 4 the order was RTT, CMT, MST. Within each session, subjects performed the tasks in the same order. For example subject number 5: in the first 25 minutes he worked on the MST alone. Still alone, in the second and third half hour he carried out the CMT and the RTT. After having changed rooms he worked with his other team members on TANDEM for another half hour. The next 1½ hours he was together with subject number 6 in one room, working on the MST, CMT and RTT consecutively. The session ended with filling out some questionnaires and then he could rest, enjoying food and drinks.

2.5 Questionnaires

The following questionnaires were administered:

1 *Fitness:* on arrival, subjects were asked to point out how they spent the day before the experiment (calm or hectic), how many hours of sleep they had, and how many alcoholic drinks they had, as compared to a normal day.

2 *Fatigue:* before the start of the actual experiment (baseline), and after every session, subjects filled out a slightly adapted version of the 'Experienced Load Scale' (SEB) (Meijman, 1992).
3 *Mood:* before the start of the actual experiment (baseline) and after every session, subjects filled out a short version of the Profile of Mood Scale (POMS) (Wald, 1984), without the fatigue scale. The four scales used were: Depression, Tension, Vigour and Anger.
4 *Performance Assessment Form:* after every task (which means every half hour) subjects had to assess the quality of their own performance, as compared to previous sessions.
5 *Cohesion Questionnaire:* before the start of the actual experiment and after every session subjects were asked to assess the team climate and the quality of the team performance. The questionnaire consists of two parts: both task oriented cohesion and social cohesion are measured. The items were gathered from two existing scales (Zaccaro, Gualtieri & Minionis, 1995; Ellemers, 1993).
6 *Final Questionnaire:* at the end of the experiment, subjects were asked to write down their experiences with working in presence of another person (in pairs). They were asked in which condition they performed best on the three different tasks. Furthermore, a question on social support was added: in order to find out to what extent subjects experience support from others in 'surviving' the experiment.

2.6 Feedback

At the end of every session, subjects got feedback on their performance. The feedback scores provided were like common Dutch school marks, ranging from 1 (very bad) to 10 (very good). The school marks for the MST and the CMT were based on the results of previous studies (Van Orden & Gaillard, 1996; Van Orden, Gaillard & Langefeld, 1996). For the RTT new reference values had to be set, since the RTT used in this experiment was a self paced version, whilst in previous studies a machine paced version was used. For TANDEM, it was even harder to make up reference scores, since it was the first time the task was used in such a context. In the end it was decided to use the scores from the subjects' training sessions as input for Table III. For all tasks, the ranges of the school marks were selected in such a way that most subjects would receive moderate to good scores (6, 7 or 8) (see Table III). The feedback scores were based on the average scores from both social conditions (alone and in pairs).

Feedback was provided in public, which means that all scores were written on a large sheet of paper that was fixed on the wall in the rest room. All subjects could see the scores of their own and the other group. Half of the subjects got feedback on their individual scores, the other half only got group scores. Feedback conditions differed *between* nights: in the first and the third night subjects got individual feedback; in the second and fourth night subjects got group feedback. Group scores were based on the average of the four team members in two conditions (eight scores in total).

Table III Feedback scores.

'school mark'	RTT	MST	CMT	TANDEM
1	0<200	0<176	0	
2	200<300	176<204	1<3	
3	300<400	204<232	3<10	
4	400<500	232<260	10<20	<0
5	500<600	260<288	20<40	0<375
6	600<700	288<335	40<50	375<750
7	700<900	335<370	50<60	750<1125
8	900<1100	370<392	60<80	1125<1500
9	1100<1275	392<400	80<94	1500<1750
10	1275-	400-	94-	1750-

2.7 Analyses

Results were analysed per session, feedback and social condition:

- session: over five sessions per night *(session 1-5)*;
- feedback: on individual or group level *(individual or group feedback)*;
- social condition: working alone or in presence of another person *(alone/pair)*.

The measures *number of incorrect responses* and *number of misses* on the RTT, MST and CMT were not normally distributed. Therefore, a logarithmic transformation was carried out on these data. *Number of correct responses* and *number of processed trials* did not have to be transformed in this way. Analyses of variance (ANOVA) were carried out using STATISTICA.

In this study, the individual tasks were all self-paced. That makes it possible to compare the effects of fatigue on these three tasks. For the RTT, the MST and the CMT standardized Z-scores were calculated, in order to compare the three.

Furthermore, the results of the MST and CMT were compared with the results of the previous study (Van Orden, Gaillard & Langefeld, 1996). The previous experiment (1996-I) was similar to this one, but differed in three aspects.

- In the previous experiment a machine-paced version of the RTT was used. This time, RTT was self-paced, which made it possible, to compare it directly to the MST and the CMT.
- In the previous study TANDEM was not used. Instead, several group activities such as sports and games were done every session, in order to increase group cohesion. Team tasks that produce real scores, were only used in the fourth session. As opposed to the previous study, in this study team performance measures were collected every session.
- The most important change is that in the previous study subjects had a chance to get a group *bonus*, and therefore only the *combined* effects of bonus and feedback could be studied. In the current study feedback was provided without a bonus.

By comparing the two studies, it is possible to gain insight into the separate stimulating effects of bonus and feedback in extremely tiring situations. Table IV summarizes which experimental conditions were compared.

Table IV Experimental conditions previous and this study.

	individual feedback	group feedback
group bonus	previous study (1996-I)	previous study (1996-I)
no bonus	this study (1996-II)	this study (1996-II)

3 RESULTS

3.1 Individual tasks

3.1.1 RTT

As can be seen from Figure 2, performance deteriorated over sessions. This was the case with all three measures (*correct responses, incorrect responses,* and *misses*). From the third session onwards, subjects seemed to profit from working in pairs. This interaction between social condition and session was significant both for *correct responses* and *misses*. A main effect of social condition only occurred with *misses:* overall, subjects missed less targets when working in pairs, as compared to working alone. Between the two feedback conditions, there were no significant differences.

Table V F-values from the analyses of variance for the RTT (interactions with p-values $> .05$ are left out).

	correct responses	log (incorrect)	log (misses)
feedback	n.s.	n.s.	n.s.
alone/pair	n.s.	n.s.	9.13**
session	30.06***	8.03***	13.98***
fb*alone/pair	n.s.	n.s.	n.s.
fb*session	n.s.	n.s.	n.s.
alone/pair*session	3.52**	n.s.	3.77**

* $p < .05$; ** $p < .01$; *** $p < .001$

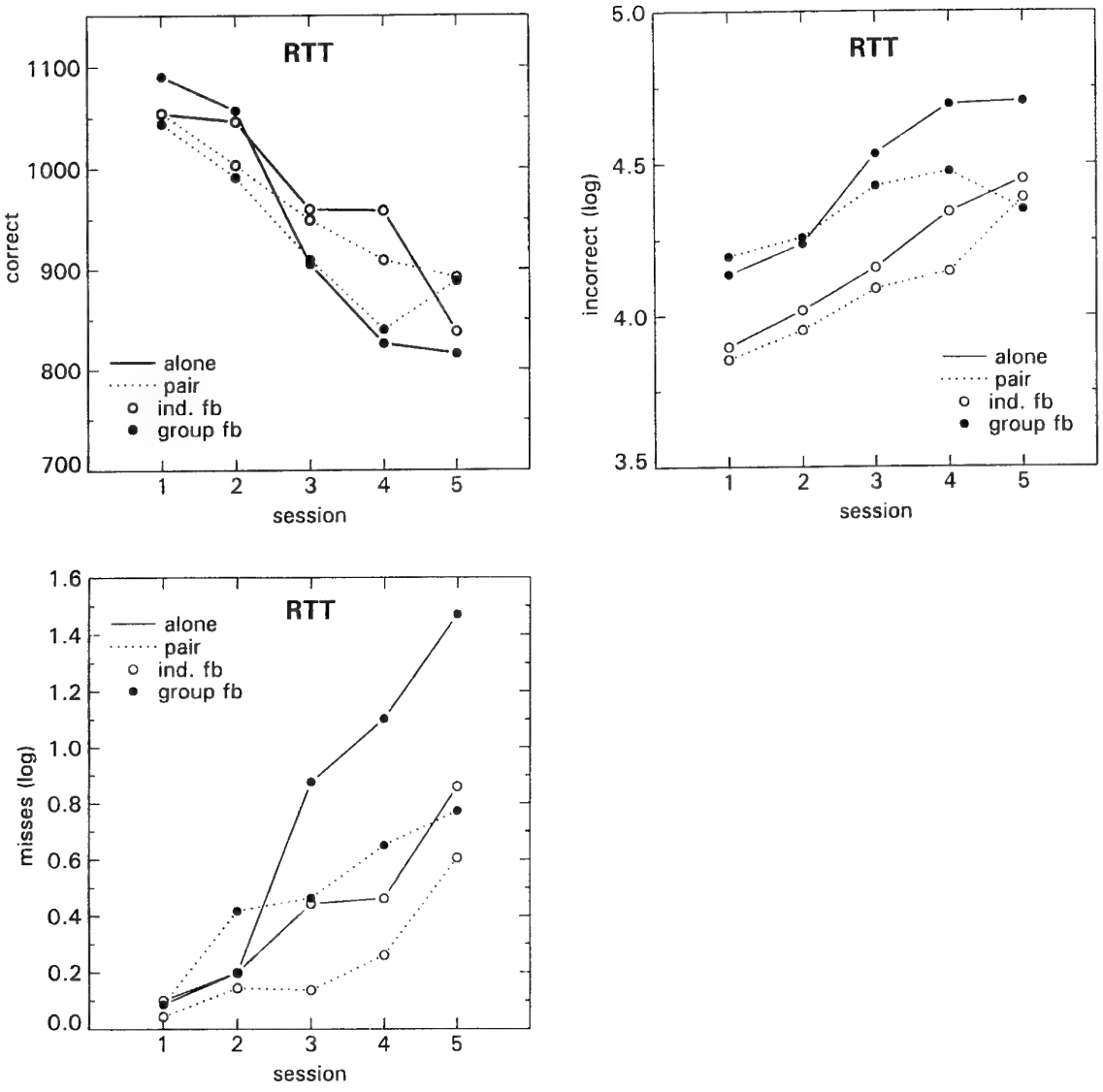

Fig. 2 Results on the RTT per feedback and social condition, as a function of session: correct responses, incorrect responses (log), misses (log).

3.1.2 MST

The results of the MST are very similar to those of the RTT. Over sessions, performance decrements occurred on all three measures. Figure 3 shows that subjects working in pairs outperformed subjects who work alone, especially in the last two sessions: pairs produced more *correct responses* and less *misses*. A main effect of social condition only occurred for the measure *misses*. As with the RTT, there were no significant differences between the two feedback conditions.

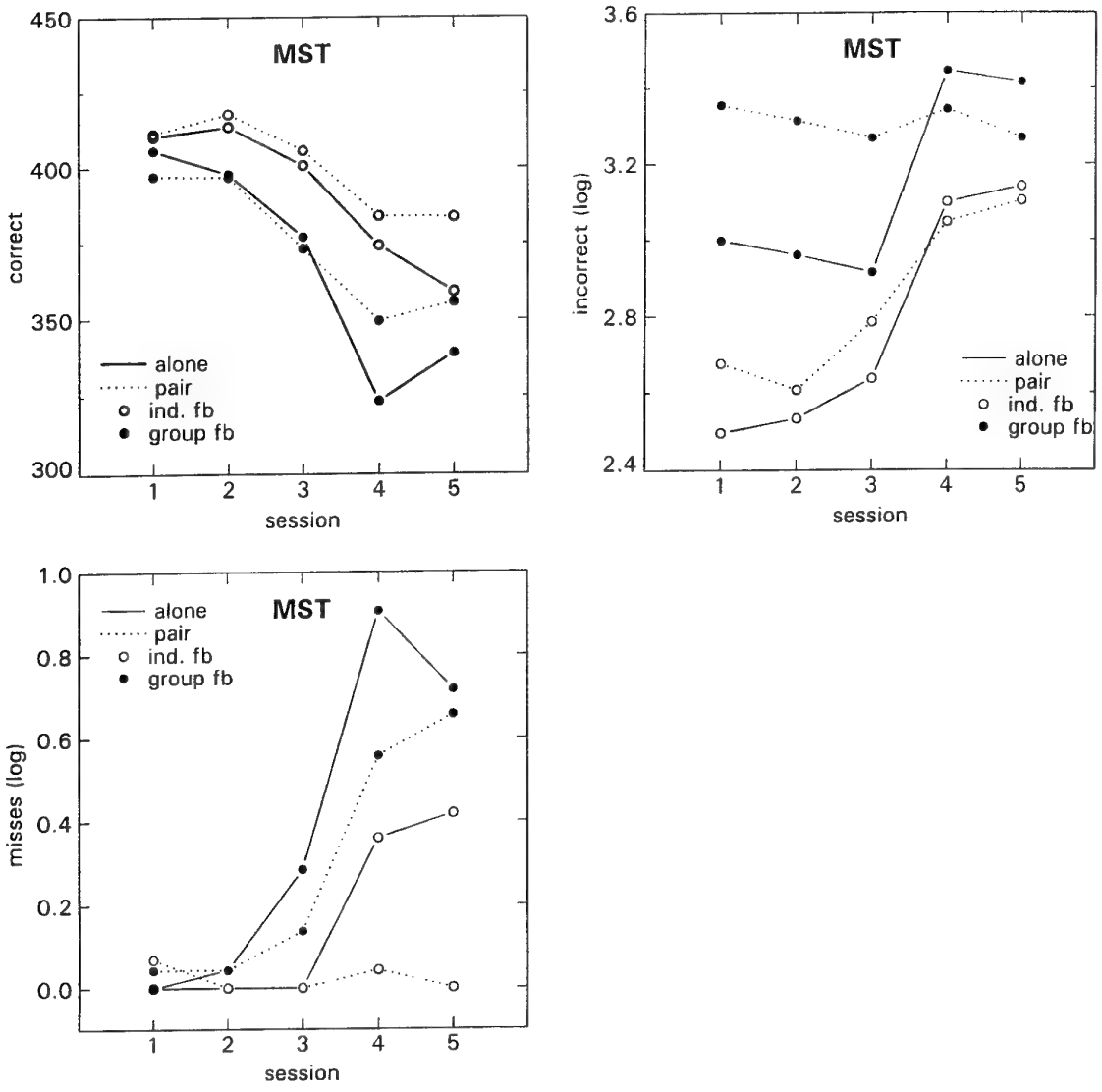

Fig. 3 Results on the MST per feedback and social condition, as a function of session: correct responses, incorrect responses (log), misses (log).

Table VI F-values from the analyses of variance for the MST (interactions with p-values >05 are left out).

	correct	log (incorrect)	log (misses)
feedback	n.s.	n.s.	n.s.
alone/pair	n.s.	n.s.	5.29*
session	28.87***	6.57***	7.11***
fb*alone/pair	n.s.	n.s.	n.s.
fb*session	n.s.	n.s.	n.s.
alone/pair*session	3.97**	n.s.	3.27*

* $p < .05$; ** $p < .01$; *** $p < .001$

3.1.3 CMT

Performance on the CMT seemed not strongly influenced by fatigue. In the second and third session, subjects processed more *trials* and they produced more *correct responses* than in the first, in the last two sessions this improvement came to a halt: performance deteriorated a little again. As far as the feedback conditions is concerned, the CMT was the only individual task in which subjects with individual feedback clearly outperformed the subjects with feedback on a group level. This was a main effect, there were no interaction effects with session. There were no significant differences between subjects working in pairs and the ones working alone.

Table VII F-values from the analyses of variance for the CMT (interactions with p-values $> .05$ are left out).

	correct	processed trials
feedback	14.78***	8.71**
alone/pair	n.s.	n.s.
session	4.80**	3.91*
fb*alone/pair	n.s.	n.s.
fb*session	n.s.	n.s.
alone/pair*session	n.s.	n.s.

* $p < .05$; ** $p < .01$; *** $p < .001$

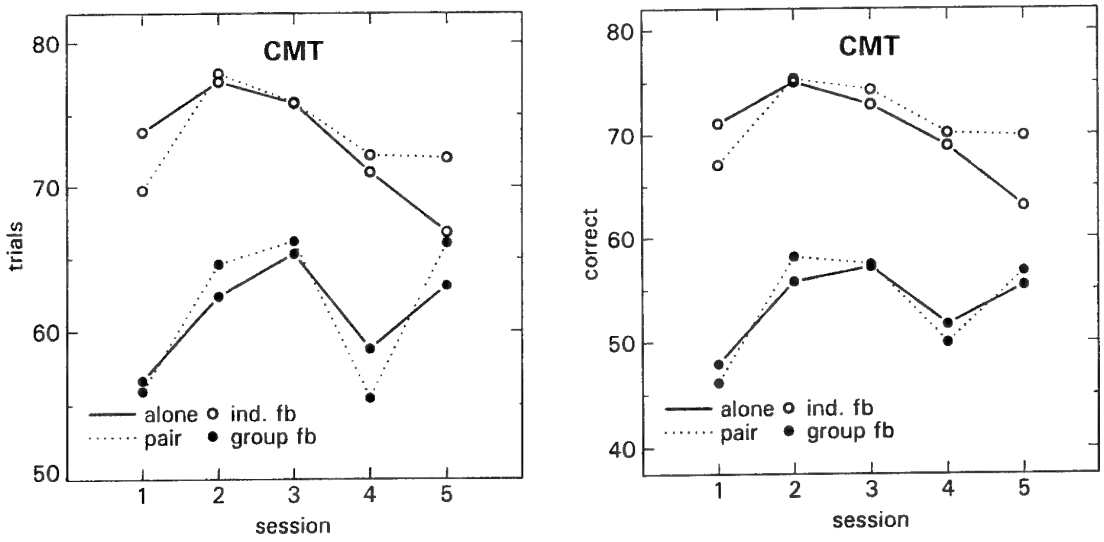

Fig. 4 Results on the CMT per feedback and social condition, as a function of session: number of trials, correct responses.

3.2 Team task

Sleep deprivation seemed to have no effect on the TANDEM-scores. Subjects kept improving their performance over sessions: *individual scores* increase over time, the *number of queries* decreases, as well as the *total query time*. This implies that even after four training sessions, teams still had not reached asymptote. They still found more efficient ways to exchange information, or found other strategies that lead to higher scores. Subjects in the individual feedback condition outperformed the ones in the group feedback condition. This was the case with all three measures. Apart from this main effect, there was an interaction with session for the *individual score*. This means that subjects in the individual feedback condition improved their performance even more than the ones in the group feedback condition.

It is not clear whether these highly significant effects really are due to the different feedback conditions. Between the separate teams, there also were significant differences in *individual scores* and *number of queries*. Overall, teams 7 and 8 were poor teams, that did not progress very much over sessions, whilst team 1 was a relatively strong team (see Figure 5). Apart from this main effect, there were also interaction effects with session, for all three measures, which implies that some teams improved their performance more over time than others. This suggests that the feedback effect can be attributed to the large differences in proficiency between the teams.

Table VIII F-values from the analyses of variance for TANDEM (interactions with p-values $> .05$ are left out).

	individual score	number of queries	total query time
team (8)	188.19***	11.97***	n.s.
feedback	677.77***	33.62***	n.s.
session	292.06***	103.98***	6.46**
team*session	18.41***	6.35***	2.27**
fb*session	10.61***	n.s.	n.s.

* $p < .05$; ** $p < .01$; *** $p < .001$

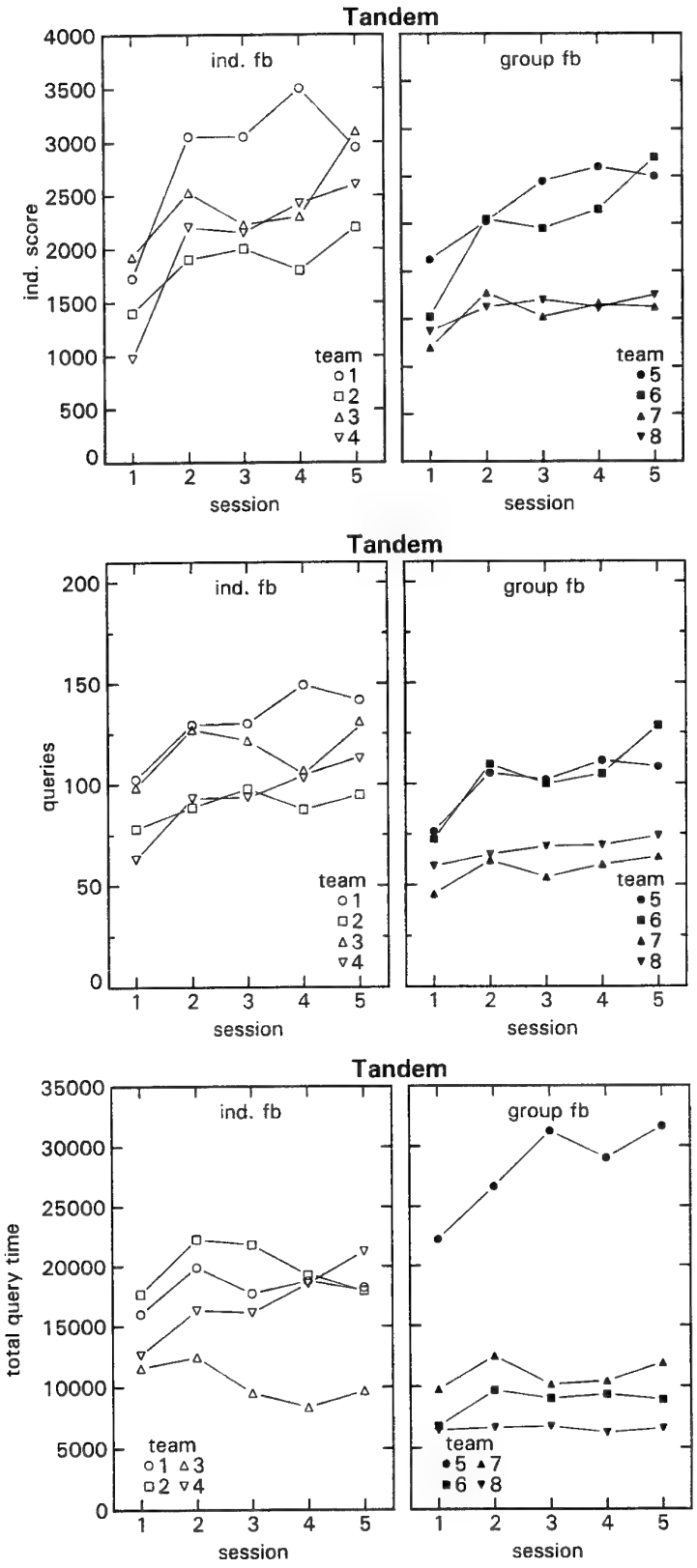

Fig. 5 Results of TANDEM per team and feedback condition, as a function of session: individual scores, number of queries, total query time.

3.3 Questionnaires

Fitness

Unfortunately, there were significant differences in 'sleep quality' between the two feedback conditions. On average, subjects in the individual feedback condition had more hours of sleep the night before the experiment than the subjects in the group feedback condition [$t=2.90$; $p<.01$]. This is not necessarily a problem, since subjects in the individual feedback condition also reported to sleep more hours in general, so not just the night before the experiment [$t=2.14$; $p<.05$]. This means that subjects in the group feedback are used to getting less sleep. Therefore, it might be concluded that although the two conditions differed in amount of sleep, the 'fitness' of the subjects in the two conditions was about the same.

POMS

Scores on the 'depression' and 'tension' scales did not change significantly over sessions. Scores on the 'anger' scale increased over time [$F(5)=4.66$; $p<.001$], and scores on the 'vigour' scale decreased [$F(5)=26.03$; $p<.001$].

SEB

Subjects reported to get increasingly fatigued over sessions [$F(5)=63.15$; $p<.001$].

Cohesion

Cohesion did not change significantly over sessions. Contrary to what was expected, subjects in the individual feedback condition reported higher cohesiveness than subjects in the group feedback condition, both on the task dimension [$F(5)=5.63$; $p<.05$] and the social dimension [$F(5)=8.45$; $p<.01$]. This might be due to the fact that reaching high scores has a positive effect on cohesiveness. This effect might be stronger than the actual cohesiveness manipulation in itself (providing group feedback).

Performance Assessment Form

RT: Conform reality, subjects thought their performance on the RTT decreased over time [$F(4)=3.82$; $p<.01$]. As compared to subjects in the individual feedback condition, subjects in the group feedback condition thought they performed better when working in pairs, than when working alone [$F(1)=5.12$; $p<.05$]. However, looking at the actual performance measures, this interaction effect was not significant.
Furthermore, subjects in the group feedback condition thought their performance deteriorated over sessions, more so than subjects in the individual feedback condition reported [$F(4)=2.59$; $p<.05$]. Again, this interaction effect could not be found in the actual performance data.

GZT: Quite rightly, subjects thought their performance deteriorated over sessions [$F(4)=5.82$; $p<.001$].
No other significant effects were found on this measure.

CMT: No significant effects were found on this measure.

Final Questionnaire

No significant effects were found on this measure.

3.4 Comparison of individual tasks

Since in this study all three individual tasks (RTT, MST and CMT) were self paced tasks, it was possible to compare the three, to see which task is affected most by fatigue. For all three individual tasks, standardized Z-scores were calculated. An analysis of variance was carried out on the three tasks together, for one measure, namely *correct responses* (see Table IX).

There are significant differences between the three tasks (see Figure 6):

- There is a significant interaction between task and social condition: the effects of working in pairs differ per task. With the MST, subjects produced more *correct responses* when they worked in pairs than when they worked alone; with the CMT it does not seem to make any difference; with the RTT *correct responses* was higher for subjects who work alone. This corresponds with the analyses of the individual tasks, as presented in Tables V, VI and VII. Further analyses (planned comparisons) show that *correct responses* on the MST differs significantly from that on the RTT [$F(1,30)=13.54$; $p<.001$]. CMT does not differ significantly from either RTT or MST.
- There is a significant interaction between task and session: decreases in *correct responses* especially occurred on the RTT and MST; on the CMT decreases in *correct responses* were smaller. Further analyses (contrast-analysis of the scores in sessions 5 and 1) show that the CMT differs significantly from the RTT and the MST [$F(1,30)=61.58$; $p<.001$], but that the RTT and the MST do not differ from each other.

Furthermore, there is some similarity between the results of this analysis and those of the separate analyses:

- There is a main effect of session: in general, the performance deteriorated over sessions. In Figures 2, 3 and 4, that show the data from the individual tasks, can be seen that this effect is mainly due to the RTT and the MST; the CMT seems less sensitive to fatigue;
- There is a significant interaction between social condition and session: over time, subjects kept their performance on a higher level when working in pairs, as compared to working alone. As can be seen in Tables V, VI and VII, this effect is due to the RTT and the MST. With the CMT, no such effect occurred.

Table IX F-values from the analyses of variance for all individual tasks measure: number of correct responses, standardized Z-scores (interactions with p-values $> .05$ are left out).

session	30.58***
task*alone/pair	4.28*
task*session	18.11***
alone/pair*session	3.08*

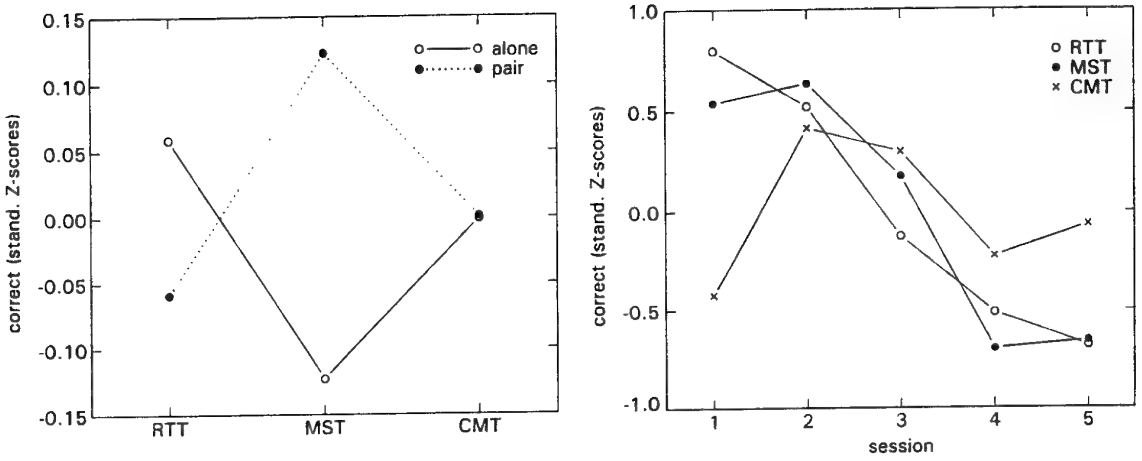

Fig. 6 Results on the three individual tasks (RTT, MST, CMT), per social condition (alone/pair), and session.

3.5 Analysis of 1996-I and 1996-II pooled data

3.5.1 Analyses of variance

For the MST and the CMT, the data from the present study (1996-II) and the previous one (1996-I) could be pooled. For the RTT this was not possible, since two different versions of the RTT were used: machine paced and self paced. First of all, analyses of variance were carried out for the whole data set, using 'group' as a dependent variable. Four groups can be distinguished:

1 individual feedback, group bonus (1996-I)
2 group feedback, group bonus (1996-I)
3 individual feedback, no bonus (1996-II)
4 group feedback, no bonus (1996-II).

The dependent variables were tested by:

- session (1-5)
- group, as described above (1-4)
- social condition (alone/pair).

Table X F-values from the analyses of variance, per group, for the MST and CMT, experiments 1996-I and 1996-II pooled.

	MST			CMT	
	correct	log (incorrect)	log (misses)	trials	correct
group (1)	3.25*	n.s.	2.79*	n.s.	3.77*
alone/pair (2)	5.31*	6.49*	4.38*	5.00*	n.s.
session (3)	47.32***	13.74***	14.30***	13.84***	13.96***
group*alone/pair	n.s.	n.s.	n.s.	n.s.	n.s.
group*session	3.23***	3.60***	1.87*	2.07*	n.s.
alone/pair* session	n.s.	n.s.	3.38*	n.s.	n.s.
1*2*3	2.33**	n.s.	n.s.	n.s.	n.s.

3.5.2 Effects of group: bonus and feedback

There were significant differences between the four groups. For the MST, subjects in the two individual feedback conditions seemed to outperform those in the group feedback conditions. This main effect of group occurred for two of the three measures: *correct responses* and *misses*. For all three measures, there was an interaction between group and session, which means that the subjects with individual feedback showed smaller performance decrements than the subjects with group feedback (see Figure 7). More detailed analyses (planned comparisons) show that in session 4 both the individual feedback/no bonus condition and the individual feedback/group bonus condition differ significantly from the group feedback/group bonus condition [$F(1,60)=4.54$; $p<.05$; $F(1,60)=9.66$; $p<.01$, respectively]. In session 5, however, only the individual feedback/group bonus condition differs from the group feedback/group bonus condition [$F(1,60)=5.77$; $p<.05$]; the significant difference between the individual feedback/no bonus condition and the two group feedback conditions has disappeared in session 5. Subjects in the two group feedback conditions scored about equally high, whether they receive a group bonus or not. This suggests that bonus has no positive effects for subjects who get group feedback, whilst it has an *extra* effect for subjects who get individual feedback.

For the CMT, the differences between the four groups are of another kind. Again, at least as far as *correct responses* is concerned, subjects in the two individual feedback conditions outperformed those in the group feedback conditions. However, contrary to what would be expected, subjects with individual feedback and no bonus, performed better than the ones with

individual feedback and a group bonus. Poorest were subjects with group feedback and no bonus.

In Figure 7 can be seen that on the MST performance deteriorated over sessions, whilst for the CMT performance increased over time (especially from session 1 to session 2). This again shows that the effects of fatigue and sleep deprivation are influenced by the cognitive complexity of the task, as was described in the previous paragraph.

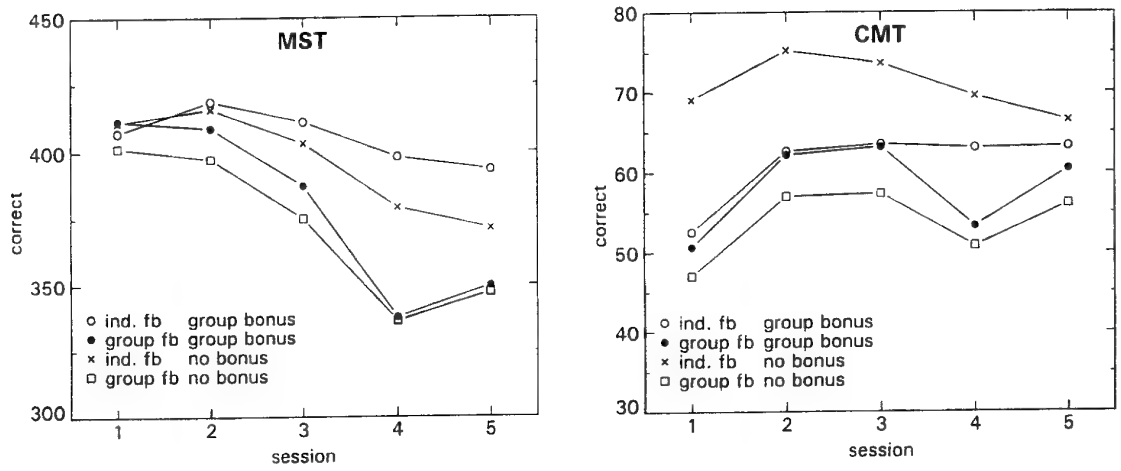

Fig. 7 Number of correct responses per group, as a function of session, for MST and CMT.

3.5.3 Effects of social condition: alone/pair

When looking at the results on the MST and CMT in the current experiment (as described in § 3.1.2 and 3.1.3), it can be seen that with the MST, subjects profited from working in pairs, especially in the last two sessions. With the CMT it did not seem to make much difference whether subjects worked alone or in pairs. A *main* effect of working in pairs only occurred with one measure: *misses* on the MST. After pooling the data from experiments 1996-I and 1996-II, even stronger effects appeared. For both the MST and the CMT, there was a main effect of working alone versus in pairs (see Table X). Both tasks were carried out better by subjects who worked in pairs. Table X shows no interaction between social condition and session.

4 DISCUSSION AND CONCLUSIONS

4.1 Discussion

In the current experiment the effects of fatigue on individual tasks (RTT, MST, and CMT) and a team task (TANDEM) were studied. The potential fatigue compensating effects of some aspects in the social environment were studied. Subjects worked on individual tasks either alone or in another person's presence. Furthermore, public feedback was provided to the subjects. Half of the subjects got feedback on their individual scores, half of the subjects only got group scores. The results of this experiment could be compared with those of the previous, in which feedback was combined with group bonuses. The comparison could only be made for the MST and the CMT; for the RTT it was not possible, because a different version of this task was used.

Task and fatigue

Subjects worked almost continuously for about 24 hours. The results from the fatigue questionnaire showed that subjects felt significantly more tired in the course of the experiment. This was reflected in the performance measures as well.

As far as the individual tasks are concerned, there were clear differences between RTT and MST on the one hand, and CMT on the other. Both with the RTT and the MST, performance deteriorated significantly over time. Subjects were able to assess rather well their own deteriorations in performance. Every half hour they had to assess their performance on the task they had performed. In line with the performance results, they reported performance losses on the RTT and MST, but not on the CMT. With the CMT, performance increased from the first session to the second, which suggests a learning effect. This is not surprising, since from other studies it is known that performance on this task can keep rising, even after 8 weeks of daily practice (Hockey & Sauer, 1996). Although subjects had more time to practise than in the previous experiment, they still improved their performance over the experimental sessions. One training session apparently is not enough to reach asymptote on this task. In the last two sessions, performance slightly decreased again. Performance levels in the first and the last session were about equal. This suggests that even with the CMT a fatigue effect occurs, but that it is less pronounced than in the other tasks, because of the learning effect.

Since all individual tasks were self-paced in this experiment, they could directly be compared through standardised Z-scores. This showed that RTT and MST differ significantly from CMT, but not from each other. RTT and MST seem to be affected more by fatigue than the CMT. One should take into account that learning effects might have overshadowed fatigue effects on the CMT, but it seems legitimate to pose that RTT and MST are more or less of the same cognitive complexity whilst CMT is cognitively more complex, or intrinsically more stimulating, and therefore is affected less by fatigue.

The individual tasks used in this study seemed to be more affected more by sleep deprivation and fatigue than the team task. With the team task TANDEM, there was a very strong session effect, but in the 'wrong' direction: performance levels kept rising, they did not deteriorate at all. There are three possible explanations for the fact that performance on the team task did not deteriorate over time:

1 Learning effects are stronger than fatigue effects: it is surprising that even after four training sessions, teams kept improving their performance. Based on the TANDEM literature, it was expected that teams would reach asymptote after about one hour of practice (Weaver, Bowers & Morgan, 1996);
2 TANDEM is intrinsically more motivating than the individual tasks;
3 People are less prone to fatigue effects if they work in a team.

From the results of this study, no definite conclusions can be drawn on this matter. The only way to test this, is by designing a study in which TANDEM is carried out by both experienced teams, and single task performers (technically it is possible to have TANDEM done by one person only). Using such a design, it can become clear whether it is the task or the team that keeps subjects fit. Learning effects can be avoided, by using experienced subjects only.

Social facilitation

Looking at the data from the current experiment only, it can be concluded that subjects profited working in pairs, especially in the last two sessions. When working in pairs, subjects produced more *correct responses* and less *misses* over time, on both RTT and MST. *Main* effects were found on one measure only, namely *misses*. This means that subjects missed less targets when they worked in pairs than when they worked alone, in all sessions. For the CMT, it did not make much difference whether subjects worked alone or in pairs.

These results prove that CMT on the one hand and RTT and MST on the other hand, differ in cognitive complexity and stimulating properties. When subjects get tired in the course of the experiment, their general level of activation decreases. With simple tasks, such as RTT and MST, there is a risk that the activation level gets too low to actually be able to perform well. In that case, another person's presence can be beneficial. For the CMT, a more complex task that is more interesting as well, no such activation problems occur, and therefore, another person's presence does not make much difference.

When the data set from the current and the previous experiment are pooled (32 subjects per condition), *main* effects of working in pairs are found on both the MST and the CMT[1]. On both tasks, subjects worked better in pairs than alone. This proves again that working in pairs indeed is beneficial.

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[1] To memorise: the data from the RTT could not be pooled, since two different versions of the task were used.

When looking at the Performance Assessment Forms, subjects do not experience any difference between working alone and in pairs, contrary to what is found in the performance data. The only exception occurred with the RTT: subjects in the group feedback condition thought they performed better when working in pairs then when working alone. In the actual performance data, the interaction between feedback condition and working alone or in pairs is, however, not significant. In fact, it is striking that subjects did not report that they performed better when working in pairs, especially in the later sessions. They were not able to notice the beneficial effects of working in pairs, not even when they get extremely tired.

Feedback and bonus

In groups that were provided with feedback on the group score only, social loafing was expected to occur. Subjects in the individual feedback condition were expected to perform better than the subjects in the group feedback condition. Looking at the results of the current experiment only, this hypothesis was not confirmed. With the RTT and MST, there were no effects of feedback at all. With the CMT, however, subjects with individual feedback did outperform those with group feedback. So, in the current experiment, the hypothesis that social loafing would occur in the group feedback condition, only seemed to be confirmed with the CMT. There are two possible explanations for the fact that the feedback manipulation was only successful with the CMT:

1 RTT and MST are very boring tasks. Motivation losses occur anyway; the potential social consequences of getting individual feedback in public are not able to prevent motivation losses.
2 The feedback effect that is found on the CMT is not a real feedback effect, but is caused by a difference between teams. Accidentally, the poorest individual performers all were members of two teams with group feedback, or some group processes, other than the feedback manipulations, were responsible for the results found.

However, some more information on the effects of individual and group feedback was gathered from the pooled data set from the current and the previous experiment: a different picture appeared. With the MST, subjects in the two individual feedback conditions outperformed those in the two group feedback conditions, especially in the last two sessions; the four feedback and bonus conditions did differ significantly from each other. Post-hoc tests showed that this effect was mainly due to the individual feedback/group bonus condition from the previous experiment (see Figure 7a).
Providing a bonus was of no use for subjects who got group feedback: performance in both group feedback conditions was equally poor. For subjects in the individual feedback conditions, however, a bonus prevented performance decrements even more.

For the CMT, contrary to what was expected, the subjects with individual feedback *without* a bonus, performed better than the ones with individual feedback and a group bonus. To explain this counter-intuitive effect, it is worth to remember that the training conditions were not the same for the four groups. In experiment 1996-II, subjects came to the laboratory to

train the TANDEM-task, and in the meantime they also practised the CMT for 20 minutes. In experiment 1996-I, subjects only got a short introduction to the task, no real practice session. In that case, a performance increase is expected from session 1 to session 2. This can indeed be seen in Figure 7b for the two groups of 1996-I (with a group bonus). For the two groups of 1996-II (without a bonus) such a learning effect was not expected. These subjects were expected to produce high scores, right in the beginning. This indeed was the case for the subjects with individual feedback (no bonus), but the subjects with group feedback (no bonus), performed worse than all other three groups. The only explanation for this finding can be that the poorest performing subjects accidentally were clustered in one experimental condition. This conclusion could be drawn from the results on TANDEM as well.

Combining the results of the three tasks in the two experiments, it may be suggested that providing public feedback on the group scores only, results in social loafing and therefore in poor performance. Providing a bonus does not help in this situation. If public feedback is provided on all group members' individual scores, people are prepared to put more effort into the task, which results in better performance. Promising a bonus to the groups with individual feedback reinforces this effect, and results in even better performance.

Nominal groups versus teams

The hypothesis on the interaction between feedback and task structure was as follows: in nominal groups it is more efficient to provide feedback on the group members' individual scores, in interdependent teams, however, it is more efficient to give feedback on the team score, since the individual team members can hardly determine their own contribution to their own individual scores. Contrary to what was expected, subjects in the individual feedback condition performed much better on both individual and team task, than those in the group feedback condition. With regard to the team task (TANDEM), this conclusion is not justified, for the following reasons:

- With the TANDEM task, the feedback manipulations may not have worked. TANDEM is constructed in such a way, that the individual team members only get a score for a correct identification of a target, as soon as the last team member (Delta) has finished his action against this target. This means that there is only very little variation in scores between the four team members. For example: suppose that Alpha has correctly identified the type of fifteen targets. If Delta has only engaged two targets, then also Alpha only get points for these two targets.
- With the TANDEM tasks, there were significant differences between the two feedback conditions, but unfortunately also between the eight teams. As can be seen in Figure 5, two teams performed significantly worse than the others. Unfortunately, these two teams both worked in the group feedback condition. This might imply that the feedback effect found, in fact is a team effect.

4.2 Conclusions

- Simple tasks such as RTT and MST suffer more from fatigue and sleep deprivation than more complex tasks such as CMT and TANDEM.
- With individual tasks people favour from working in the presence of another person, as compared to working alone. This is especially the case when they get tired.
- Nominal groups (group members work on individual tasks, and the group score is based on the average individual scores) work better if they are provided with public feedback on their individual scores. Providing them with a group score only, causes social loafing.
- Nominal groups that are provided with feedback on the group score only, do not favour from the prospect of a bonus. However, if individual feedback is given, a bonus might incite them to perform even better.
- The hypothesis that individual feedback is only efficient for nominal groups, but not for interdependent teams, could not be tested in the current experiment.

4.3 Suggestions for future research

1 In the current experiment, some changes in the design were made as compared to the previous study. The implications of these changes cannot be completely overseen. Especially the effects of adding TANDEM to the test battery might have been more radical than one would expect at first sight. Subjects enjoyed the TANDEM task very much, they were more awake after having carried out TANDEM, and this might have had a positive effect on the other tasks. Therefore, it could be wise, to replicate this experiment, using the old design.

2 Although a comparison was made between this experiment and the previous, and some insight was gained on the individual effects of bonus and feedback, it is still not clear whether the effect of feedback is due to the motivating effect of feedback itself, or to the social consequences, caused by giving the feedback in public. In the design used so far, no distinction is made between the motivating effect of feedback and the social loafing factor. To do this, a follow up study will be designed, in which individual feedback is given either in public, or to the individual only.

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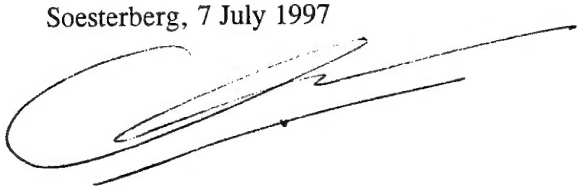

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10. TITLE AND SUBTITLE

Effects of fatigue and social environment on performance: individual and team tasks

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14. SUPPLEMENTARY NOTES

15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTES))

The current experiment is the fifth in a series of studies that investigate the effects of fatigue and social environment on task performance. The following topics were studied: [a] Which tasks are most vulnerable to fatigue? [b] To what extent can the presence of another person during task performance compensate fatigue effects? [c] To what extent can 'social loafing' be prevented by giving a group public feedback on all group members' individual performance? [d] Does feedback motivate even without a bonus? [e] Does the type of feedback (individual or group feedback) have to be adjusted to the type of task (individual or interdependent team task)?
Subjects, divided into four-person groups, worked 20 hours continuously (five sessions of four hours each) on three individual tasks that differed in cognitive complexity (RTT: Reaction Time Task; MST: Memory Search Task; CMT Contaminant Monitoring Task), and on a team task (TANDEM). The individual tasks were carried out both alone and in presence of another subject. Half of the subjects got (public) feedback on all group members' individual scores, the other half only got a group score.
The tasks differed in their sensitivity to fatigue. Performance on the two simplest tasks (RTT and MST) deteriorated most over night, compared with the more complex CMT and the team task. One should realise, however, that during the experiment a rather strong learning effect occurred on both the CMT and the team task. This learning effect might have interfered with the fatigue effects. Nevertheless, it can be concluded that cognitive complex, and therefore maybe also more interesting tasks, are less vulnerable to fatigue than simple tasks.
In general, subjects performed better on the individual tasks when they worked in presence of another subjects, as compared to alone. This was especially the case in the last sessions. So, the more tired one is, the more one profits from working with someone else. Subjects who got feedback on their individual scores performed better than those who got group feedback. It seems that 'social loafing' indeed can be prevented by making all individual group members' scores public. A comparison with the previous experiment shows that the performance of subjects who get individual feedback is even better if they are promised a bonus.
Providing individual feedback is thought not to be very effective when people work on interdependent team tasks, since in such tasks they can hardly influence their own individual performance. This hypothesis that individual feedback is only efficient with individual tasks and that group feedback is better with interdependent team tasks, unfortunately could not be tested in this experiment, because there was too little variance in the individual scores on the team task.

16. DESCRIPTORS	**IDENTIFIERS**
Feedback Social Facilitation Social Loafing Sustained Work	Performance Teamwork

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